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TECHNICAL MEMORANDUM

To UNCLASSIFIED X-551

By authority of CSTAR V.8 No. 24 Date 12/3/70 Blm 3-8-71

LARGE-ANGLE MOTION TESTS, INCLUDING SPINS, OF A FREE-FLYING DYNAMICALLY SCALED RADIO-CONTROLLED 1/9-SCALE MODEL OF AN ATTACK AIRPLANE

By Charles E. Libbey and Sanger M. Burk, Jr.

Langley Research Center
Langley Air Force Base, Va.

NOFORN and USGA&C limitations removed per NASA TD 71-67 dtd 11/11/71, s/Gifford A. Young
Aus 9/20/2004

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON October 1961

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LARGE-ANGLE MOTION TESTS, INCLUDING SPINS, OF A FREE-FLYING DYNAMICALLY SCALED RADIO-CONTROLLED 1/9-SCALE MODEL OF AN ATTACK AIRPLANE*

By Charles E. Libbey and Sanger M. Burk, Jr.

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SUMMARY

The model test results indicated that, after the stall, either an unsteady gyrating fairly steep post-stall motion or a flat fully developed spin may be encountered. Termination of the post-stall motion should be attempted immediately by forward movement of the stick before rotation starts. If the airplane does not respond to this control movement by pitching down, but rather starts turning, the rudder should be moved to oppose the yawing motion with simultaneous movement of the roll control with the rotation (stick right when turning to the right); if the rotation continues to build up, the stabilators should be moved full up while directional and lateral controls are maintained. This control disposition is optimum for terminating any erect spinning motion obtained and will be effective unless a fully developed spin occurs. Because recovery may not be possible from a fully developed spin, extreme care should be exercised to prevent it.

INTRODUCTION

At the request of the Bureau of Naval Weapons, Department of the Navy, an investigation was made to determine the post-stall and fully developed spin recovery characteristics of an unpowered free-flying dynamically scaled radio-controlled 1/9-scale model of an attack airplane, by using the radio-controlled dynamic-model testing technique which is described in references 1 and 2. The airplane is a swept-wing attack aircraft with an all-movable horizontal tail (or stabilator) for pitch control, a wing spoiler-deflector combination for roll control, and an all-movable vertical tail for yaw control. In addition to these controls, the model also utilized extendible strakes on the nose for

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yaw damping at high angles of attack (see ref. 3). Unpublished spin-tunnel test data on a 1/30-scale dynamic model of the same airplane indicated the airplane could develop a flat moderately fast rotating spin from which recovery was difficult or impossible. It was felt, however, that the spinning attitude which could be obtained readily in the spin tunnel could be, at least in part, due to the tunnel launching technique (ref. 3) and therefore the tendency for the airplane to enter the spin could not be accurately predicted solely on the basis of the tunnel tests. In order to determine if it were likely, or even possible, for this airplane to enter a spin, it was considered desirable to determine the post-stall and spin-entry characteristics of this design under L
conditions more closely simulating actual flight. The present tests, 1
therefore, were made to supplement the spin-tunnel tests and to obtain 3
a more realistic evaluation of the spin-entry characteristics of this 7
airplane. 5

The post-stall and erect fully developed spin recovery characteristics of the radio-controlled model were determined for a full-scale gross weight of 40,950 pounds with the center of gravity located at 33.1 percent of the mean aerodynamic chord. The model was tested in the clean configuration, that is, no external stores or armament were attached. For some tests, the model was prerotated to determine the spinning characteristics in a manner similar to that used in the spin tunnel. For other tests the model was launched in forward flight to determine the post-stall motions as well as to compare the resulting spinning motions with those obtained by prerotation tests.

SYMBOLS

b	wing span, ft
$\bar{c}$	mean aerodynamic chord, ft
I_X, I_Y, I_Z	moments of inertia about body X-, Y-, and Z-axis, respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter

m	mass of airplane, slugs
t	simulated full-scale time, sec
S	wing area, sq ft
V	free-stream velocity, ft/sec
W	weight, lb
X,Y,Z	orthogonal body axes with origin at airplane center of gravity
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of perpendicular distance between center of gravity and reference line to mean aerodynamic chord (positive when center of gravity is below reference line)
α	angle of attack at nose boom, deg
β	angle of sideslip at nose boom, deg
δ_h	deflection of all-movable horizontal tail (stabilator) positive with trailing edge down, deg
δ_r	rudder deflection, positive with trailing edge to left, deg
δ_s	spoiler deflection, deg
ρ	air density, slugs/cu ft
ψ_e	azimuth angle, deg
L	left stick or pedal movement to produce control deflection
R	right stick or pedal movement to produce control deflection
U	up deflection of trailing edge of stabilator
D	down deflection of trailing edge of stabilator

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MODEL FLIGHT-TEST TECHNIQUE, TEST FACILITY, AND EQUIPMENT

The model flight-test technique consists of launching from a helicopter, either in forward flight or in a prerotated condition, an unpowered dynamically scaled radio-controlled model, and of controlling its flight from the ground. Evaluation of the flight behavior is based on the model pilot's observations and the quantitative measurements obtained from motion-picture records. The testing technique is described more fully in references 1 and 2.

The flight tests were performed at an isolated airport with three 5,000-foot runways forming an equilateral triangle. Two ground stations were used for controlling the model, one for the pilot who operated the pitch controls and one for the pilot who operated the roll and yaw controls. (See fig. 1.) Each ground station was provided with a radio-control transmitter, communications equipment, and a motorized tracking unit equipped with a telephoto motion-picture camera and binoculars to assist the pilots and trackers in viewing the flight of the model. A photograph of the tracking and controlling equipment is shown in figure 2. A helicopter equipped with a special launching rig was used to launch the models. This launching rig was mounted on the side of the helicopter near the door (see fig. 3(a)) and was raised and lowered by a hydraulic hoist. When the model was ready to be launched, the rig was lowered so that the model was below the helicopter (see fig. 3(b)). The rig was constructed so that the model could be held stationary for forward launches or could be prerotated by an electric motor for spinning launches. All phases of the operation were directed by a coordinator located near the ground stations. Magnetic tape recorders were used to record control signals and all voice communications between the helicopter, coordinator, and model pilots in order to assist in analysis of test results.

MODEL CONSTRUCTION AND INSTRUMENTATION

A three-view drawing of the 1/9-scale model of the airplane is presented in figure 4, and a photograph of the model is shown in figure 5. A list of the pertinent dimensional characteristics of the full-scale airplane is given in table I. The model was constructed primarily of glass-fiber reinforced plastic. The wings and tail surfaces had solid balsa cores with a covering of glass-fiber reinforced plastic, whereas the fuselage was a 3/16-inch-thick hollow shell.

The model was equipped with electric-motor actuators which provided flicker or bang-bang control in which the spoiler-deflector combination and the rudder are moved rapidly through predetermined angular deflections in either direction from the neutral position in response to control signals and then back to neutral with the cessation of the signal. The all-movable horizontal tail, or stabilator, was moved at approximately a constant rate for pitch control by an electric actuator for as long as a radio signal was being given and remained fixed at its position at the time the signal was stopped. The strakes on the nose of the model were spring actuated and could be released by a solenoid actuated by a radio signal. Once released the strakes remained extended for the duration of the flight.

Instrumentation was used in the model to provide sufficient data for qualitative analysis of the motions of the model. A 16-millimeter motion-picture camera with a 17-millimeter wide-angle lens was mounted in the canopy of the model. This camera was positioned so as to photograph the view from the pilot's cockpit, which included flow-direction vanes attached to a nose boom on the model, and also to photograph control-position indicators and a timing light mounted on a panel in the cockpit. The flow-direction vanes were attached to the boom with swivel joints which allowed each vane to aline itself with the airstream. One vane measured both angles of attack and sideslip, and the other vane measured the resultant airstream velocity (fig. 6). The latter vane had canted fins attached to a torque rod, and the angular displacement of the fins was used to measure the resultant velocity.

RETRIEVING EQUIPMENT

The model was retrieved at the termination of the flight by means of a 21-foot-diameter flat-circular parachute. The parachute was packed in a deployment bag and installed in a compartment in the tail of the fuselage. A pyrotechnic device was used to eject the end-plate cover of the parachute compartment. This end-plate cover was attached by a short length of cord to the pilot parachute so that when it was ejected it pulled the pilot parachute into the free airstream and thus the main parachute was extracted quickly and positively.

FLIGHT TESTS

The model was ballasted to simulate dynamically the full-scale airplane flying at an approximate altitude of 31,000 feet (ρ = 0.000914 slugs/cu ft) with a gross weight of 40,950 pounds. For this condition, the total flying weight of the model was 146 pounds. The model was tested only for the clean condition (no armament or stores simulated) with the center of gravity at 33.1 percent of the mean aerodynamic chord. A comparison of the model and airplane mass characteristics is shown in table II. The Reynolds number for these tests, based on the mean aerodynamic chord, averaged about 1,240,000 and, based on the maximum fuselage depth at the canopy, averaged about 430,000.

For the majority of the flights, the model was launched in forward flight at an airspeed of about 40 knots and an altitude of approximately 3,000 feet in an attempt to obtain a spin from which recovery would then be attempted, but when a spin was not obtained, a recovery to normal flight generally was attempted from whatever motion was obtained. Ini-
tially, spins were attempted both to the right and to the left to deter- L
mine the direction in which the model was most prone to enter a spin; 1
then the remainder of the spins were conducted in this direction. At 3
the instant of launch, the rudder and spoiler deflectors generally were 7
neutral and the stabilator was set to trim the model at a relatively 5
low angle of attack. A few seconds after the model was released, back stick was applied to stall the model. The rate at which the stabilator was deflected up was varied to produce both gentle and rapid stalls. Part of the test program consisted of prerotating the model on the launch rig while the helicopter hovered at an altitude of approximately 3,000 feet. The model was then released in a flat spinning attitude generally with the rudder with the spin and the spoiler-deflectors and stabilator neutral.

From either type of launch, the spoiler-deflectors and rudder were moved in a direction to help promote a spin; for the lateral control system on this airplane, the procedure to promote a spin was indicated to be stick left and rudder right in a right spin. When the model was launched in forward flight, the controls were moved to initiate a spin a few seconds after the model had been stalled and had begun to turn; when the model was launched in a prerotated condition, the controls were moved a few seconds after the model was released. After the spin developed, or post-stall motion ensued, controls were applied to attempt a recovery. Spin-tunnel experience has shown (ref. 3) that for airplanes with the mass distributed very heavily along the fuselage, as is the case for this airplane, provision of a pro-spin rolling moment will be very effective for recovery from a fully developed spin. Therefore, for most of the spin-recovery attempts in the present investigation, the spoiler deflectors were moved with the spin (stick right in a right spin) and the rudder was moved against the spin (rudder left in a right spin).

DATA REDUCTION

Evaluation of the flight behavior of the model was based primarily on the model pilot's observations and comments, and on quantitative measurements of the variables obtained from the motion-picture records as generally described in reference 2. Several factors are considered in determining whether the model has entered a fully developed spin or whether the motion is merely a post-stall gyration. The motion is considered to be a fully developed spin if the rate of rotation about the flight path is sustained either to the right or left and the average angle of attack generally is above the stall and greater than that which can be maintained with full-back stick in straight flight. The time histories of angle of attack and sideslip as well as of rate of rotation are generally fairly regular, although they may be oscillatory in nature. The motion is considered to be a post-stall gyration if it is a continuing large-angle motion wherein the average angle of attack generally is above the stall but there is no clearly defined continuous spinning characteristic. In general, the time histories of post-stall gyrations will be somewhat irregular.

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Spin recovery is measured from the time the controls are moved until either the spin rotation ceases or the angle of attack remains below that for the stall. The airplane recovery characteristics are considered to be satisfactory if recovery from the model spin occurs in $2\frac{1}{4}$ turns or less. A post-stall gyration is considered terminated when the angle of attack goes below that for the stall, and thus a positive effective normal control response is restored.

The basic time reference for the flight records was a timing light recorded by the model camera at a fixed frequency of one light flash each one-half second of full-scale time. The various other film records of a given flight were correlated with those of the camera on the model.

The measurements obtained from tests of the radio-controlled model and presented in terms of full-scale values are believed to be accurate within the following maximum limits, based on limitations of equipment and on repeatability of measurements:

α, deg	±4
β, deg	±4
ψ_e, deg	±10
V, ft/sec	±14
Rate of rotation, rps	±0.02
δ_r, deg	±1/2
δ_s, deg	±2
δ_h, deg	±2
t, sec	±0.5
Number of turns before recovery attempted	±1/8
Number of turns for recovery	±1/8

The measured weight and mass distribution of this model varied from desired values within the following limits during the test program:

Weight, percent	1/2 low to 1 high
Center-of-gravity location, percent $\bar{c}$	0 forward to 3 rearward
Moments of inertia:	
I_X, percent	1 high to 2 high
I_Y, percent	2 high to 4 high
I_Z, percent	0 to 2 low

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RESULTS AND DISCUSSION

A total of 22 flights was made. The model was launched seven times in a prerotated condition, and for the remaining 15 flights the model was launched in forward flight. Nine fully developed spins were obtained in 22 attempts, 4 of which were from a prerotated condition and 5 of which were from forward launches. No satisfactory recoveries were obtained from any of the spins. Two recoveries, one in 4 turns and one in $5\frac{1}{2}$ turns, were obtained by use of full-back stick, roll control full with the spin (stick right in a right spin), rudder full against the spin, and the strakes on the nose extended. All post-stall gyrations could be terminated if full-forward stick were applied.

The results of some of the model flight tests are presented in the form of full-scale time histories in figures 7 to 10 and are considered to be typical of all the results obtained. Complete motion-picture records of each of these typical flights are available on loan. A description of the film and a request card form are presented at the back of this paper, on the page preceding the abstract pages.

Model Flight-Test Results

<u>Flight 1 - spin</u>.- Time histories of the model flight 1 are given in figure 7. The model was launched in forward flight with all controls neutral. A few seconds after launch, right rudder was applied in an attempt to start the model turning to the right before it was stalled. After the model was stalled, it started turning to the right and approximately 3/8 turn later, left roll control was given. The model continued in a right fully developed spin for approximately $4\frac{1}{4}$ turns at which time recovery controls were applied, that is, rudder left against the spin, roll control right with the spin, stabilators full up, and both strakes extended. Approximately $3\frac{3}{8}$ turns later the

stabilator was moved to neutral while the other controls were maintained fixed. Although both the α and β oscillation increased somewhat (generally an indication of initiation of a recovery) recovery was not complete in $1\frac{1}{4}$ additional turns after which the retrieving parachute was deployed. The angle of attack during the spin averaged approximately 70°, and the rate of rotation was approximately 0.174 rps (full scale).

<u>Flight 2 - spin</u>.- Time histories of the model flight 2 are presented in figure 8. The model was prerotated to the right and launched with all controls neutral. The rate of rotation at the time of launch
L was approximately 0.25 rps and subsequently increased to approximately
1 0.365 rps before recovery was initiated. This rate of rotation was very
3 high and is attributed to the fact that the stabilator was neutral rather
7 than in its up position. The angle of attack during the fully developed
5 spin averaged approximately 75°. The model made nine turns with all controls neutral before recovery was attempted, that is, rudder was moved left against the spin, roll control was moved right with the spin, stabilators were moved full up, and both strakes were extended. These controls were held for four additional turns after which the model had recovered from the spin. The angle of attack remained high, about 50°, after recovery as a result of full-up stabilators and both strakes being extended.

<u>Flight 3 - post-stall gyration</u>.- Shown in figure 9 are time histories of the model in flight 3. The model was launched in forward flight with all controls neutral. The maximum rudder deflection for this flight was increased to $\pm 8^{\circ}$. Several short applications of left rudder were given before the model was stalled in an attempt to sideslip the model before the stall. After the model stalled and had made approximately one turn to the left, left rudder was applied and a few seconds later right roll control was also applied in an attempt to obtain a spin. The model made two additional turns with pro-spin controls; however, the motion about all three axes was very erratic and resulted in a post-stall gyration rather than a spin. At the end of three complete turns, the rudder and roll control were reversed but full-up stabilators were maintained. These controls were held for approximately $1\frac{1}{4}$ turns with little or no effect, and then the rudder and roll controls were neutralized while full-up stabilators were maintained. The angle of attack during this post-stall gyration averaged approximately 40°; however, it fluctuated from as low as 10° to as high as 75°, and although β averaged approximately 0°, it was also oscillatory and varied from -40° to 35°. Subsequent analysis of additional flights indicated that this motion would have been terminated by moving the stick forward.

Flight 4 - post-stall gyration.- Time histories of the model flight 4 are presented in figure 10. The model was launched in forward flight with all controls neutral and allowed to free fall for several seconds to pick up speed before stalling. The maximum rudder deflection for this flight was again ±8°. After the model was stalled (the stall occurred between an angle of attack of 25° and 30°), it started turning to the right, and two short applications of right rudder were given to aid this turn. After two complete turns the motion had not developed into a spin and termination of the motion was quickly effected by moving the stabilators full down. Although both strakes were extended during this recovery, the results of several subsequent tests for which they were not used indicate that they have little effect on the recovery from a post-stall gyration.

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Discussion of Model Flight Results

The fully developed spin results of the radio-controlled model flight tests were in very good agreement with spin-tunnel results (unpublished data) both as regards the nature of the spin and the recoveries therefrom.

It was indicated from unpublished static-force data that there would be little effect of Reynolds number on the values of α and β during the spin-entry motion ($\alpha < 50^\circ$; $\beta \approx 0^\circ$), and inasmuch as the radio-controlled model was successfully flown into a spin from forward flight 5 times in 15 attempts, it is felt that the full-scale airplane will be able to enter a fully developed spin. As regards a Reynolds number effect in the fully developed spin, it was indicated from static tests that as a result of the cross-sectional shape of the nose on this design, a pro-spinning moment on the radio-controlled model could be obtainable (ref. 3). Accordingly, strakes were installed on the nose of the model, size and location being determined from static-force tests up to an angle of attack of 90°. The strakes used were such that the forces and moments on the model at low Reynolds number were similar to the forces and moments at high Reynolds number (without strakes). For some of the flight tests of the radio-controlled model, the strakes were extended at various phases of the spin varying from the initial onset of the spin before the first turn had been completed to just as the recovery controls were applied, as many as five turns after the onset of the spin. The results obtained indicate that the Reynolds number effect was not significant on either the spin or recovery.

On some occasions the results indicated a fairly steep, unsteady, gyrating type of motion will also be encountered which will not necessarily develop into a spin. Termination of this motion should be attempted immediately by forward movement of the stick before rotation starts. If the airplane does not respond to this control movement by pitching down, but rather starts turning, the rudder should be moved to oppose the yawing motion with simultaneous movement of the roll control with the rotation (stick right when turning to the right); if the rotation continues to build up (an indication that the airplane is in the early stages of a spin) the stabilators should be moved full up while directional and lateral controls are maintained. If the rotation becomes very slow, the stick should be moved longitudinally forward. This control disposition is the optimum recovery technique from erect fully developed spins. However, unpublished spin-tunnel results have shown that in order to obtain a satisfactory recovery from a fully developed spin, 6° and -6° of differential horizontal tail will be required in addition to the optimum movement of the regular controls.

CONCLUSIONS

On the basis of tests of a 1/9-scale radio-controlled model simulating an attack airplane with a gross weight of 40,950 pounds at an approximate altitude of 31,000 feet and with the center of gravity located at 33.1 percent of the mean aerodynamic chord, the following conclusions are made:

1. A fairly flat moderately fast rotating spin is possible on the airplane from which satisfactory recoveries by normal controls would be difficult or impossible. Optimum control technique for recovery from a fully developed spin is full rudder reversal against the direction of rotation, movement of the roll controls to full with the spin (stick right in a right spin), stabilators full up. If recovery becomes imminent, the stick should be moved longitudinally forward.

2. After the stall an unsteady gyrating fairly steep post-stall motion may be encountered. Termination of this motion should be attempted immediately by forward movement of the stick before rotation starts. If the airplane does not respond to this control movement by pitching down, but rather starts turning, the rudder should be moved to oppose the yawing motion with simultaneous movement of the roll control with the rotation (stick right when turning to the right). If the rotation continues to build up, the stabilators should be moved full up while directional and lateral controls are maintained.

3. Recovery from fully developed spins may be difficult or impossible. Consequently specific instructions should be provided pilots to help them recognize the onset of a spin and to terminate any turning

tendency after the stall by rolling the airplane in the same direction in which it is turning.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., May 5, 1961.

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TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE FULL-SCALE AIRPLANE

[Values of wing and tail stations are in feet]

Length (over-all), ft	72.46
Wing:	
Span, b, ft	53.02
Area, S (including spoiler-slot deflections and 203.82 sq ft covered by fuselage), sq ft	700.00
Root chord (wing station 0), ft	22.05
Tip chord (equivalent, wing station 26.46), ft	4.41
Tip chord (theoretical, wing station 26.53) ft	4.36
Mean aerodynamic chord (wing station 10.29), ft	15.19
Distance from nose to L.E. of M.A.C., ft	37.63
Aspect ratio	4.0
Taper ratio	0.20
Sweepback, deg -	
Leading edge	43.05
0.25 chord	37.5
Trailing edge	14.97
Incidence, deg	0
Airfoil -	
Root (in streamline)	NACA 65A005 (modified)
Tip (in streamline)	NACA 65A005 (modified)
Spoiler:	
Area, sq ft -	
Inboard section	5.823
Center section	3.158
Outboard section	3.716
Total (one wing)	12.697
Span (equivalent, wing stations 10.09 to 20.21), ft	10.111
Chord (equivalent, inboard), ft	1.44
Chord (equivalent, outboard), ft	1.24
Deflector:	
Area, sq ft -	
Inboard section	5.823
Center section	3.158
Outboard section	3.716
Total (one wing)	12.697
Span (equivalent), ft	10.111
Horizontal tail:	
Area (exposed, including 0.912 sq ft cutout at inboard ends of trailing edge), sq ft	175.00
Span (including 10.67 ft covered by fuselage and nacelles), ft	31.583
Aspect ratio (exposed)	2.50
Taper ratio (exposed)	0.20
Root chord (exposed, horizontal-tail station 5.33), ft	13.94
Tip chord (equivalent, horizontal-tail station 15.79), ft	2.79
Tip chord (theoretical, horizontal-tail station 15.84), ft	2.76
Sweepback, deg -	
Leading edge	51.75
0.25 chord	45.00
Trailing edge	11.20
Vertical tail:	
Area (exposed, 2.42 ft above ref. line), sq ft	101.00
Span, ft	12.308
Aspect ratio	1.5
Taper ratio	0.35
Root chord (2.42 ft above ref. line), ft	12.16
Tip chord (equivalent, 14.72 ft above ref. line), ft	4.25
Tip chord (theoretical, 14.79 ft above ref. line), ft	4.21
Sweepback, deg -	
Leading edge	49.25
0.25 chord	45.00
Trailing edge	27.36

TABLE II.- MASS CHARACTERISTICS OF THE FULL-SCALE AIRPLANE

AND THE 1/9-SCALE MODEL

W, lb	Center-of-gravity location			Moments of inertia, slug-ft^2 (a)			Mass parameters		
	Fuselage station	$x/\bar{c}$	$z/\bar{c}$	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1/9-scale model									
146	56.90	0.331	0.055	2.64	9.67	11.72	-450×10^{-4}	-130×10^{-4}	577×10^{-4}
Model values converted to full scale at altitude of 31,000 ft									
40,950	512.10	0.331	0.055	59,982	219,707	266,284	-450×10^{-4}	-130×10^{-4}	577×10^{-4}
Full-scale airplane									
40,950	506.72	0.302	0.054	60,846	213,329	267,971	-428×10^{-4}	-153×10^{-4}	581×10^{-4}

[a]Moments of inertia are given about the center of gravity.

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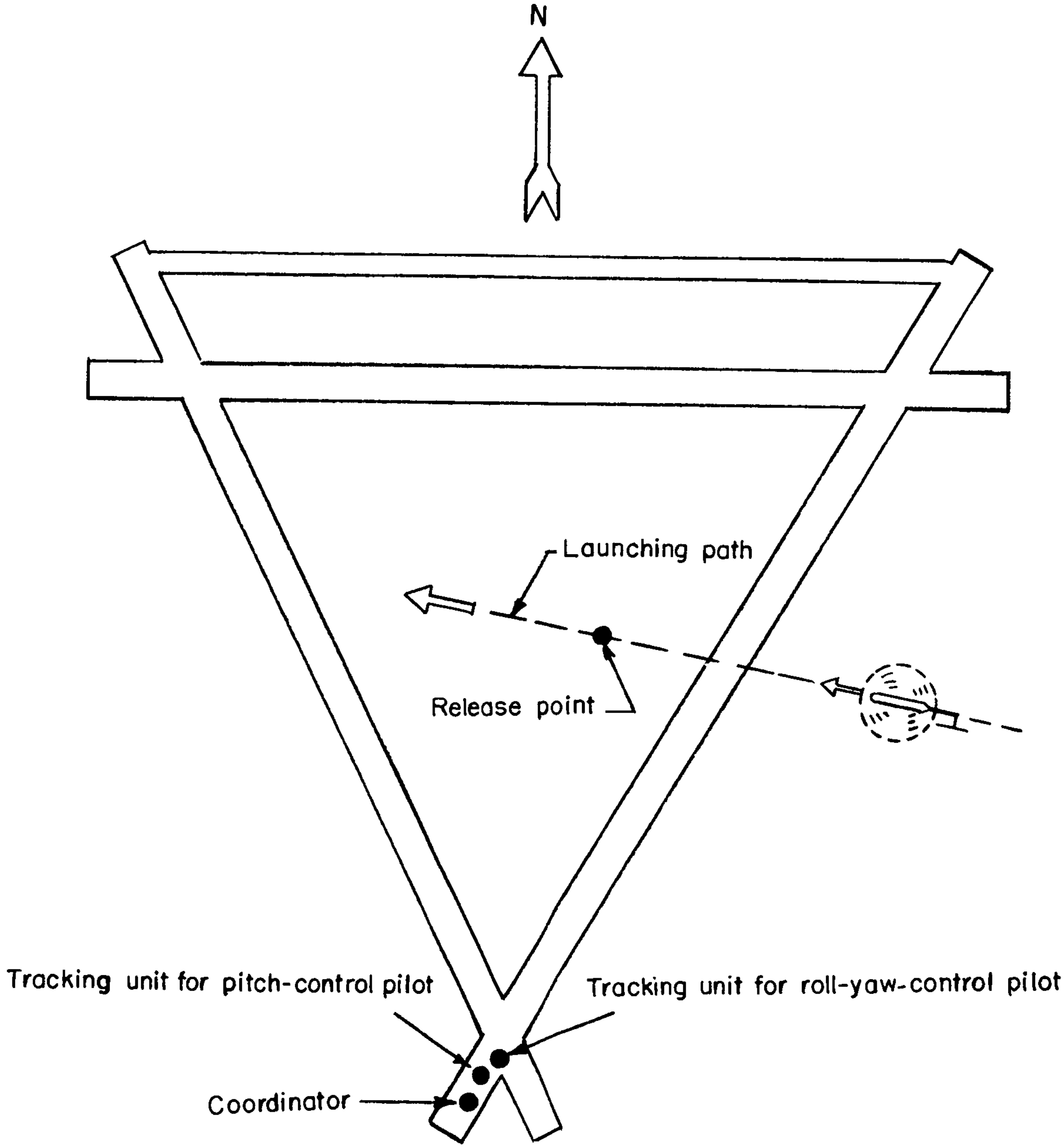

Figure 1.- Area where test program was conducted.

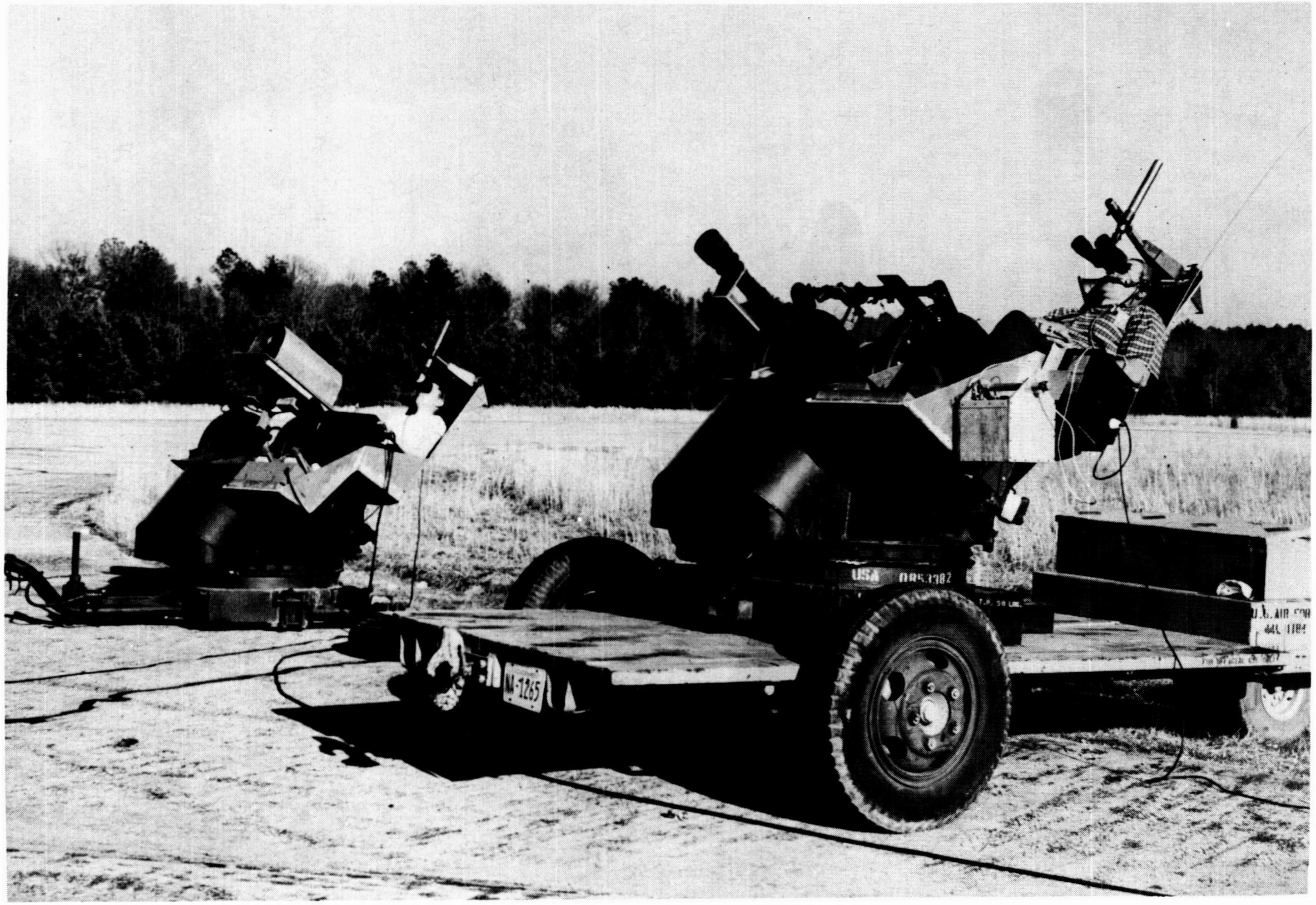

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Figure 2.- Photograph of control equipment showing the roll-yaw pilot and pitch pilot in positions.

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(a) Model raised. L-59-8479

(b) Model lowered. L-59-8482

Figure 3.- Photograph of model on launching rig in raised and lowered positions.

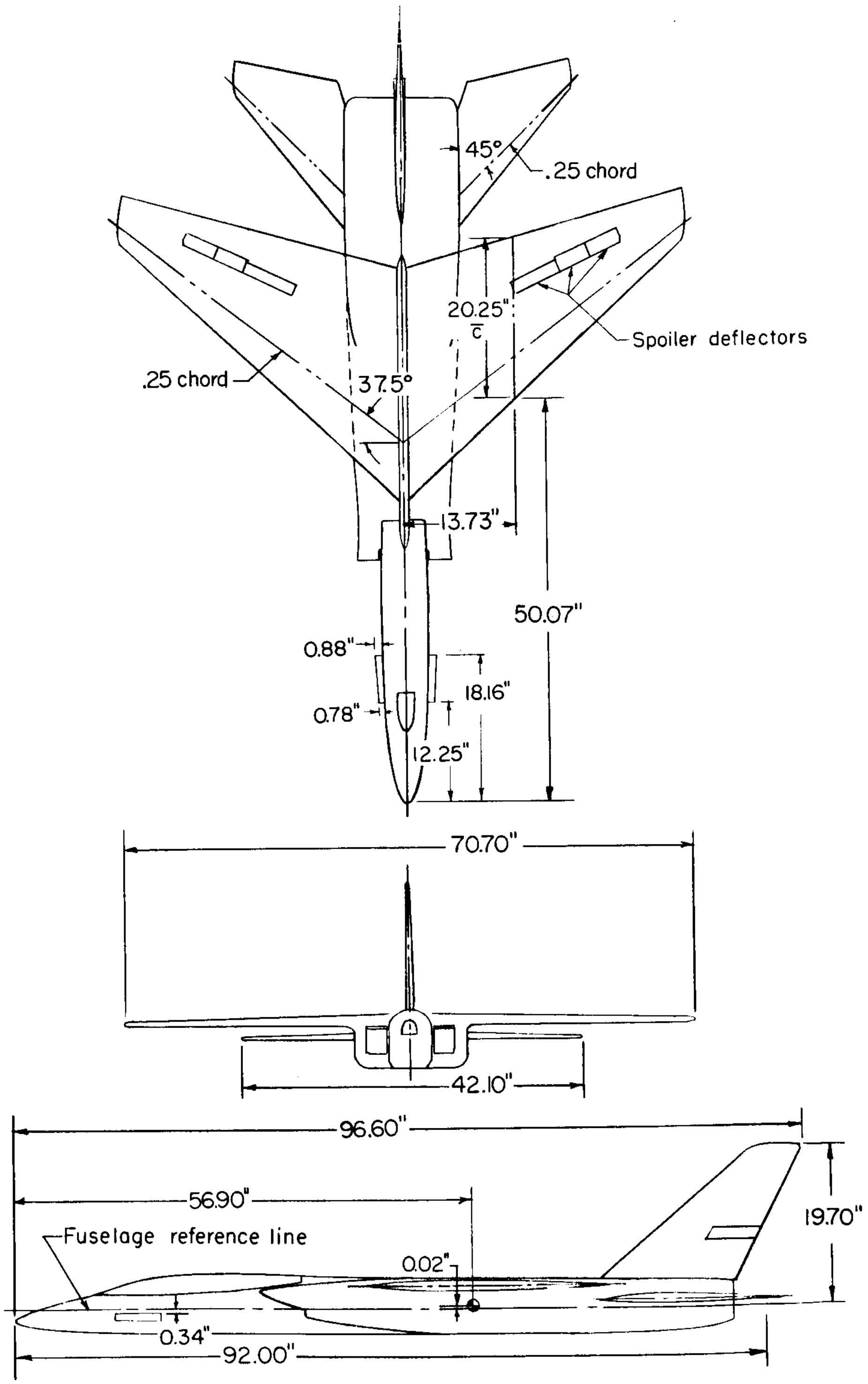

Figure 4.- Three-view drawing of model.

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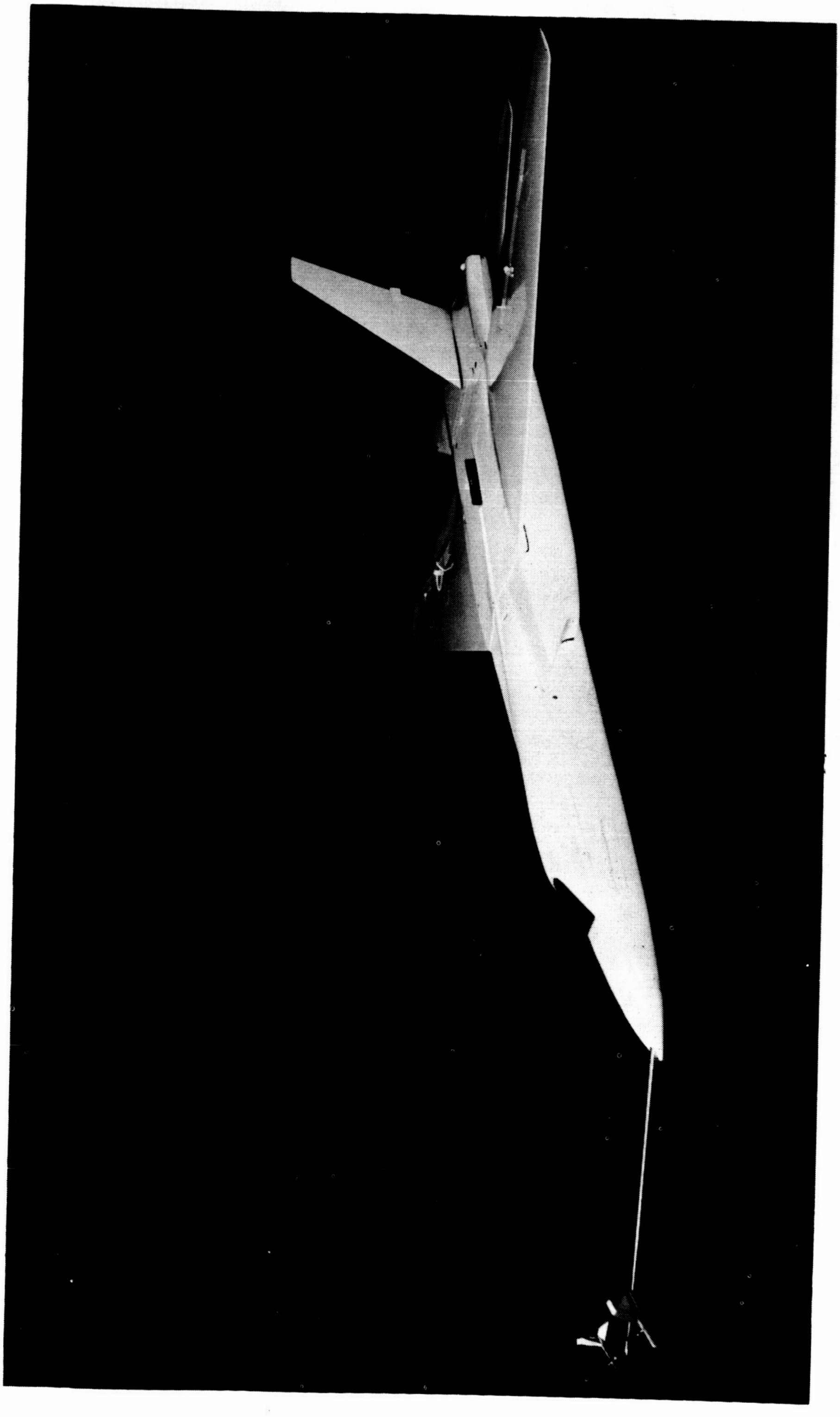

L-59-4805.1

Figure 5.- Photograph of model.

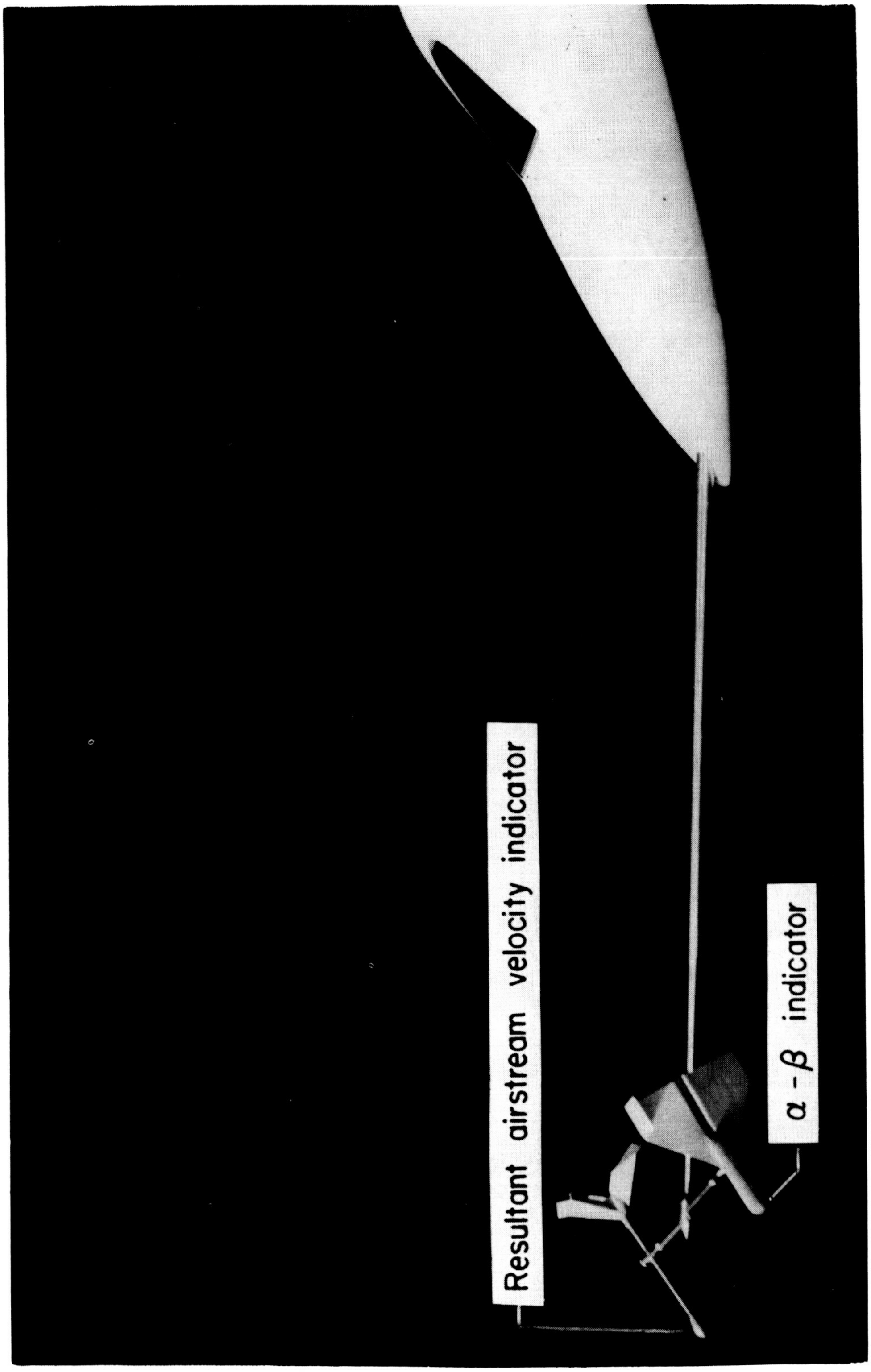

Figure 6.- Photograph showing flow-direction vanes. L-59-4805.2

L-1375

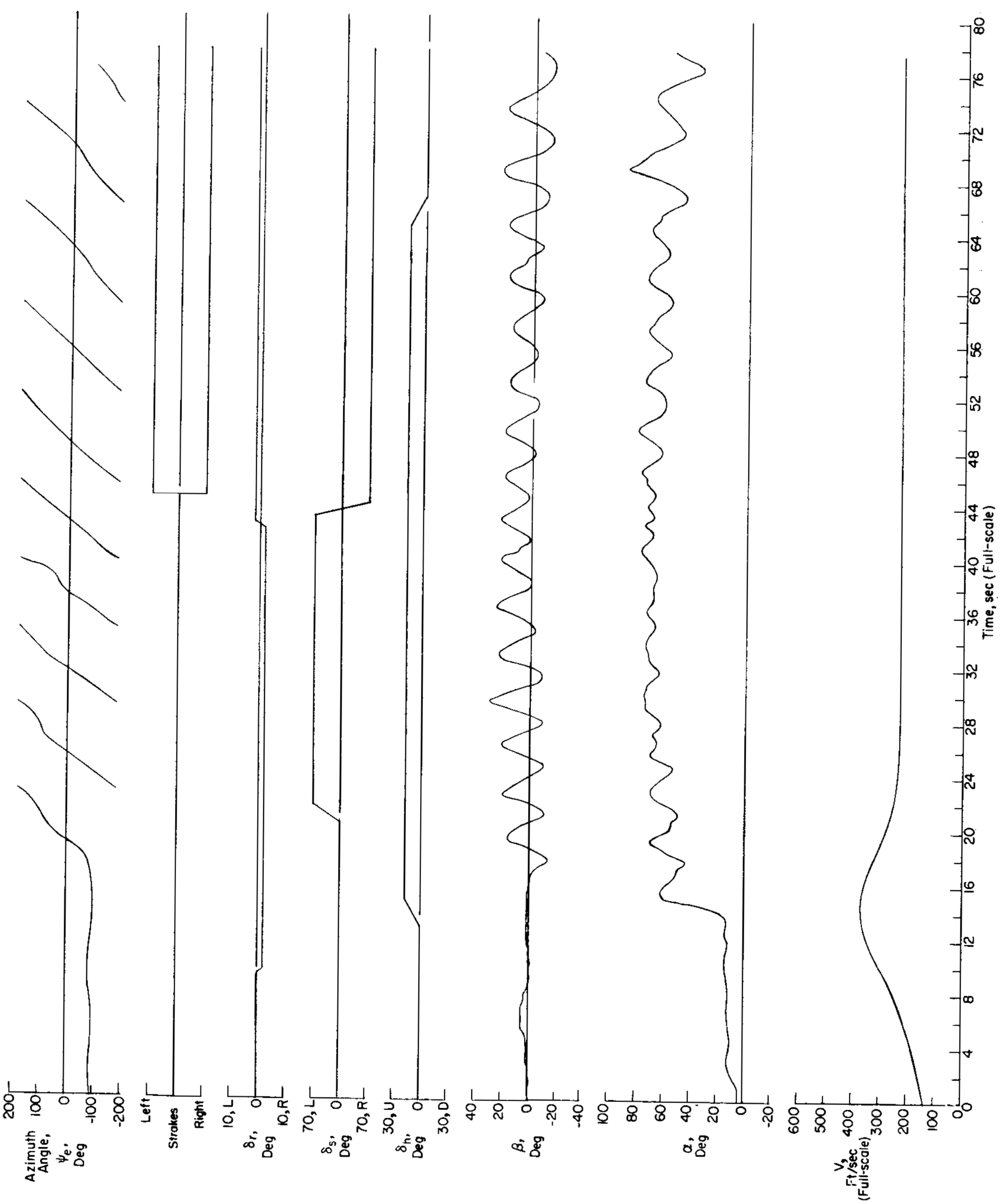

Figure 7.- Time histories of model flight 1 (spin).

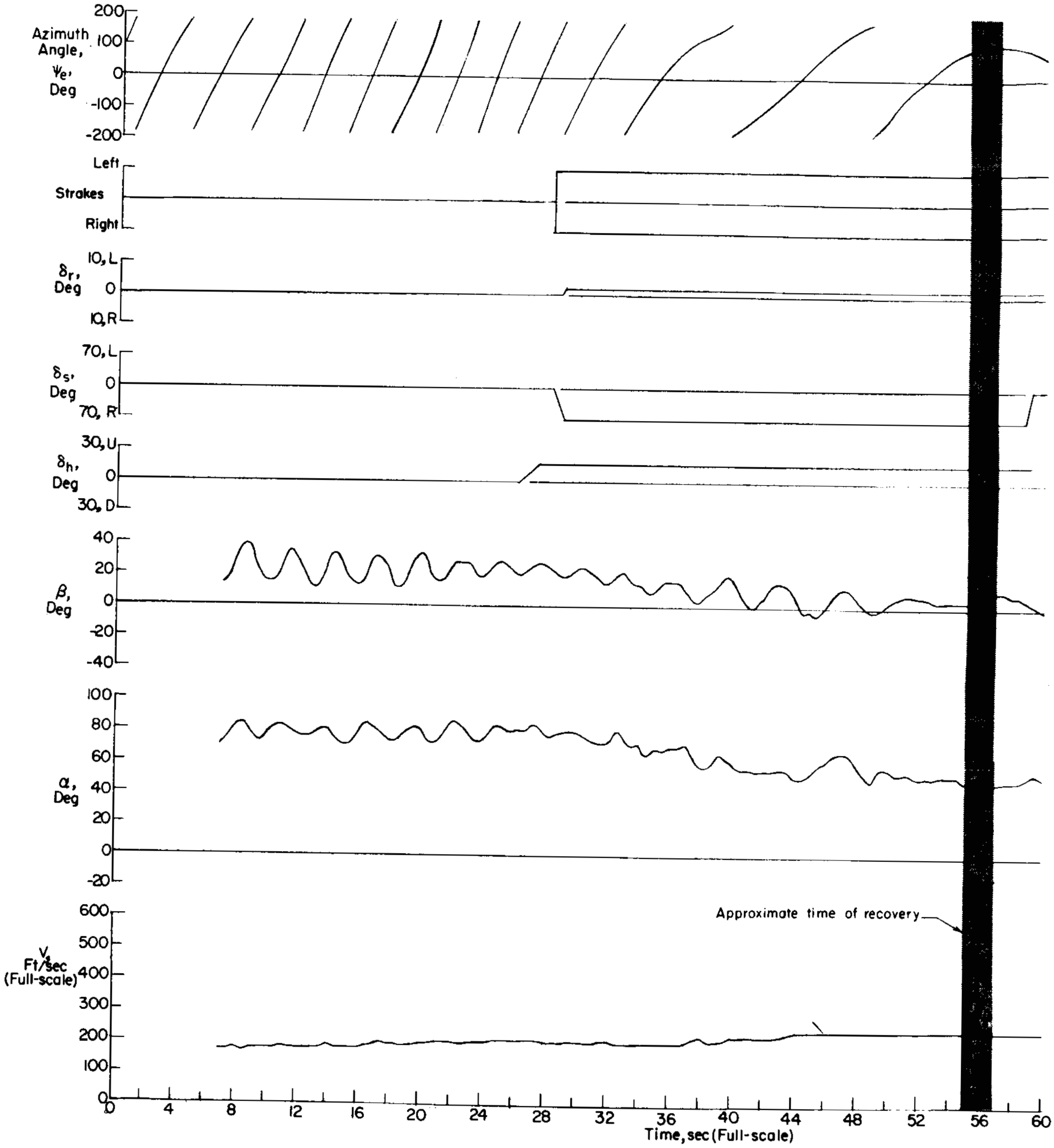

Figure 8.- Time histories of model flight 2 (spin).

L-1375

L-1375

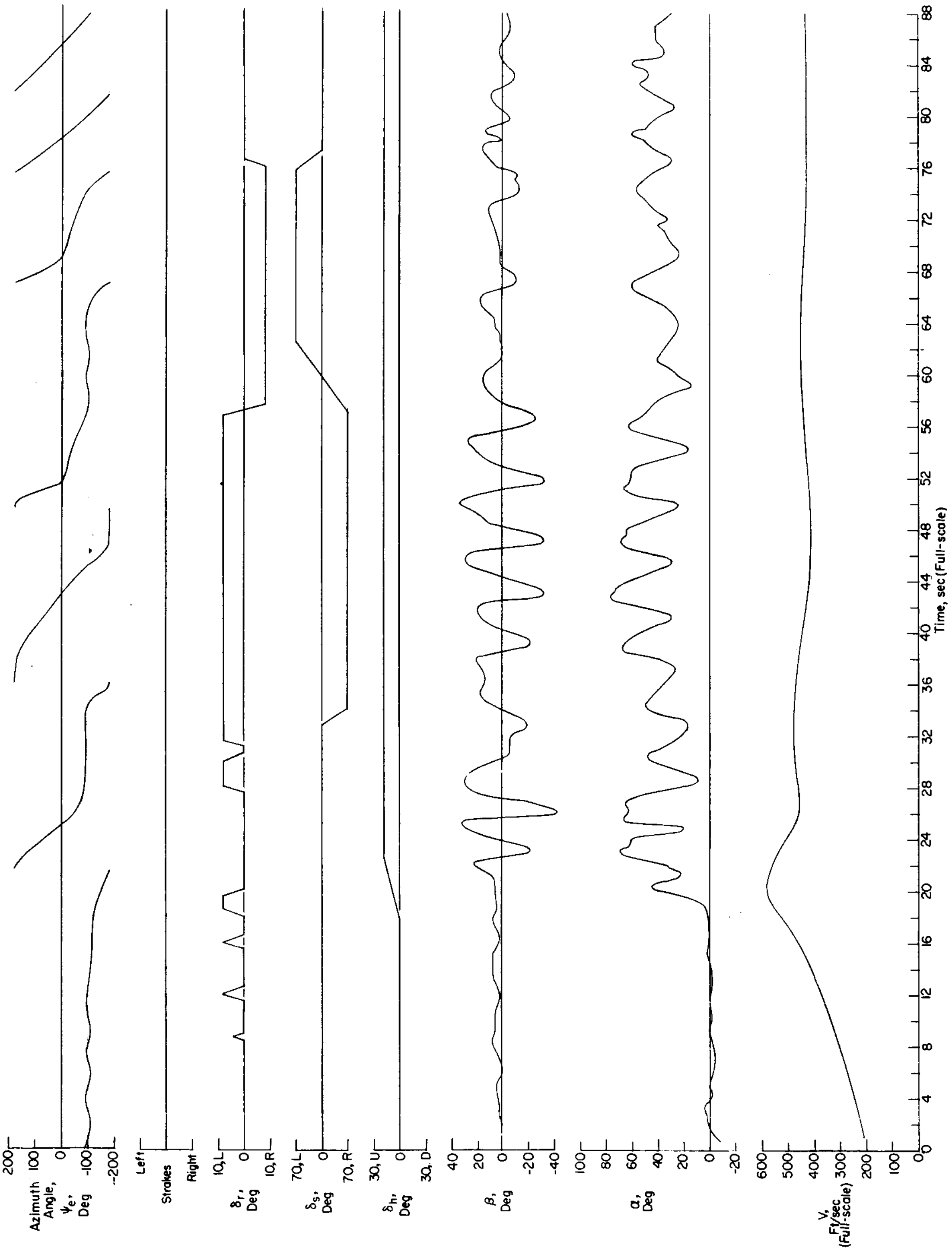

Figure 9.- Time histories of model flight 3 (post-stall gyrations).

L-1375

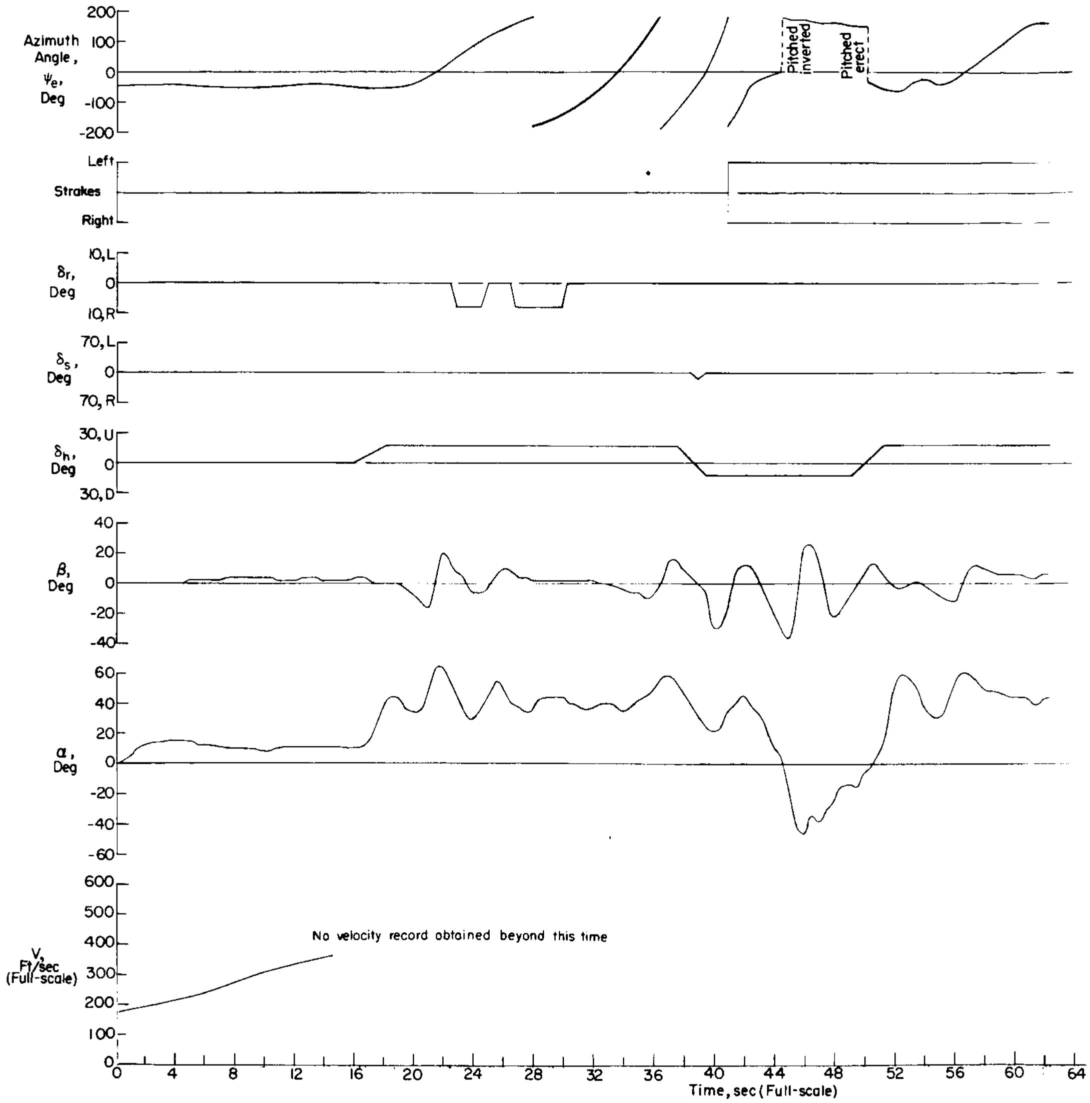

Figure 10.- Time histories of model flight 4 (post-stall gyrations).

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